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Kosugi et al.

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(54) **X-RAY RADIATION SOURCE**

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USPC 378/119–140
See application file for complete search history.

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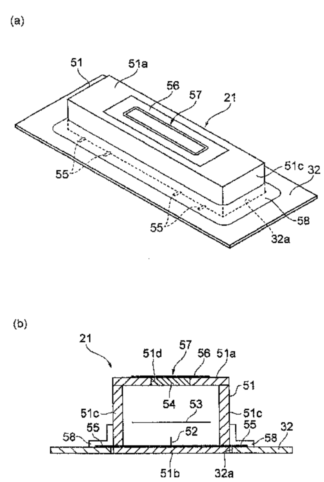
(57) **ABSTRACT**

In an X-ray radiation source, a lid part is fastened to a main part with screws, so that an X-ray tube is secured to a housing while being pressed against an inner surface of the wall part a by a first circuit board. The X-ray tube can be secured stably within the housing by thus being held between the first circuit board and the wall part. The X-ray radiation source uses the first circuit board incorporated in the housing itself for pressing the X-ray tube. This makes it unnecessary to provide new members for pressing the X-ray tube and can prevent the device structure from becoming complicated.

7 Claims, 13 Drawing Sheets



(51) **Int. Cl.**

H05G 1/70	(2006.01)
H01J 35/18	(2006.01)
H01J 35/04	(2006.01)
H05G 1/06	(2006.01)

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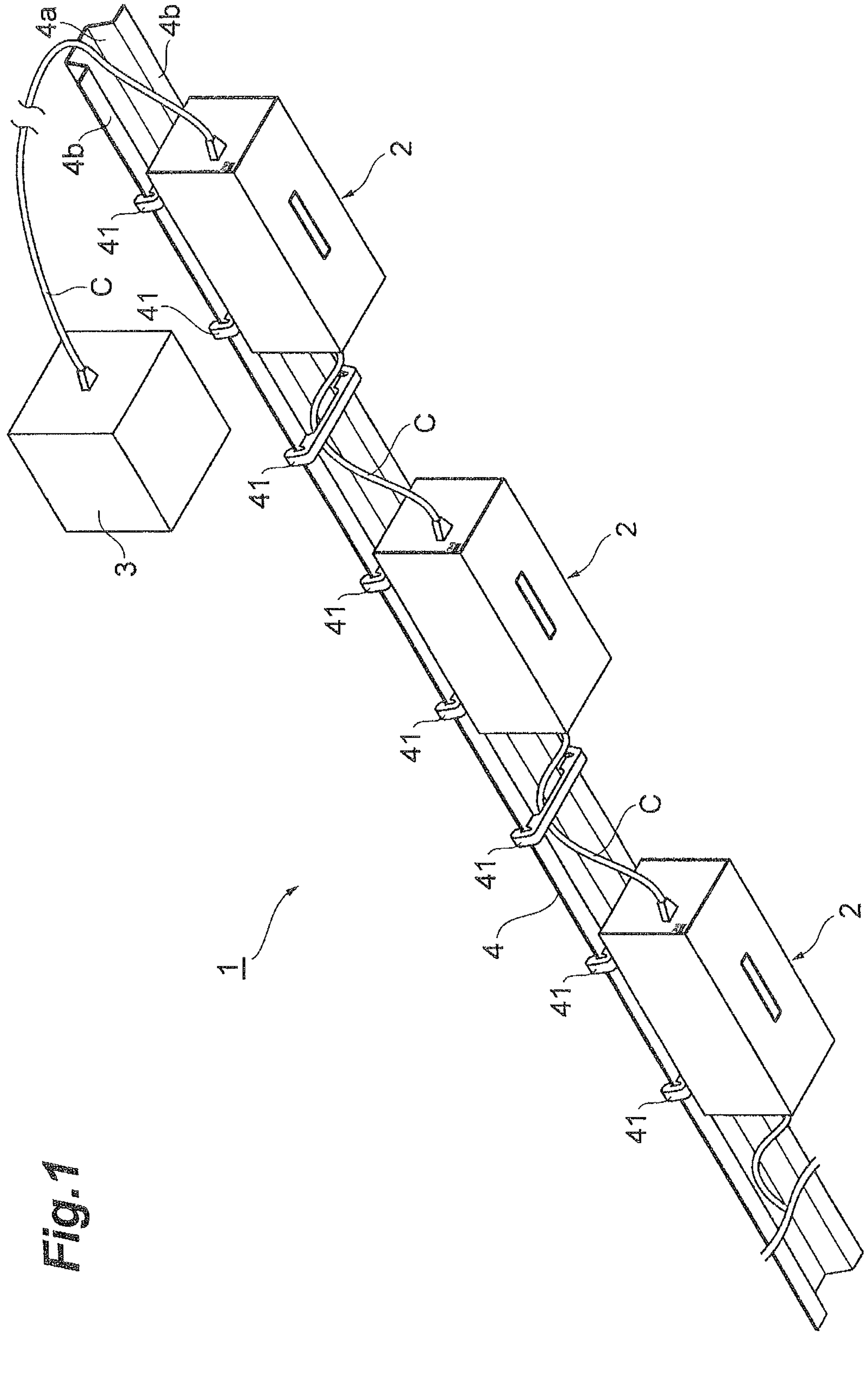
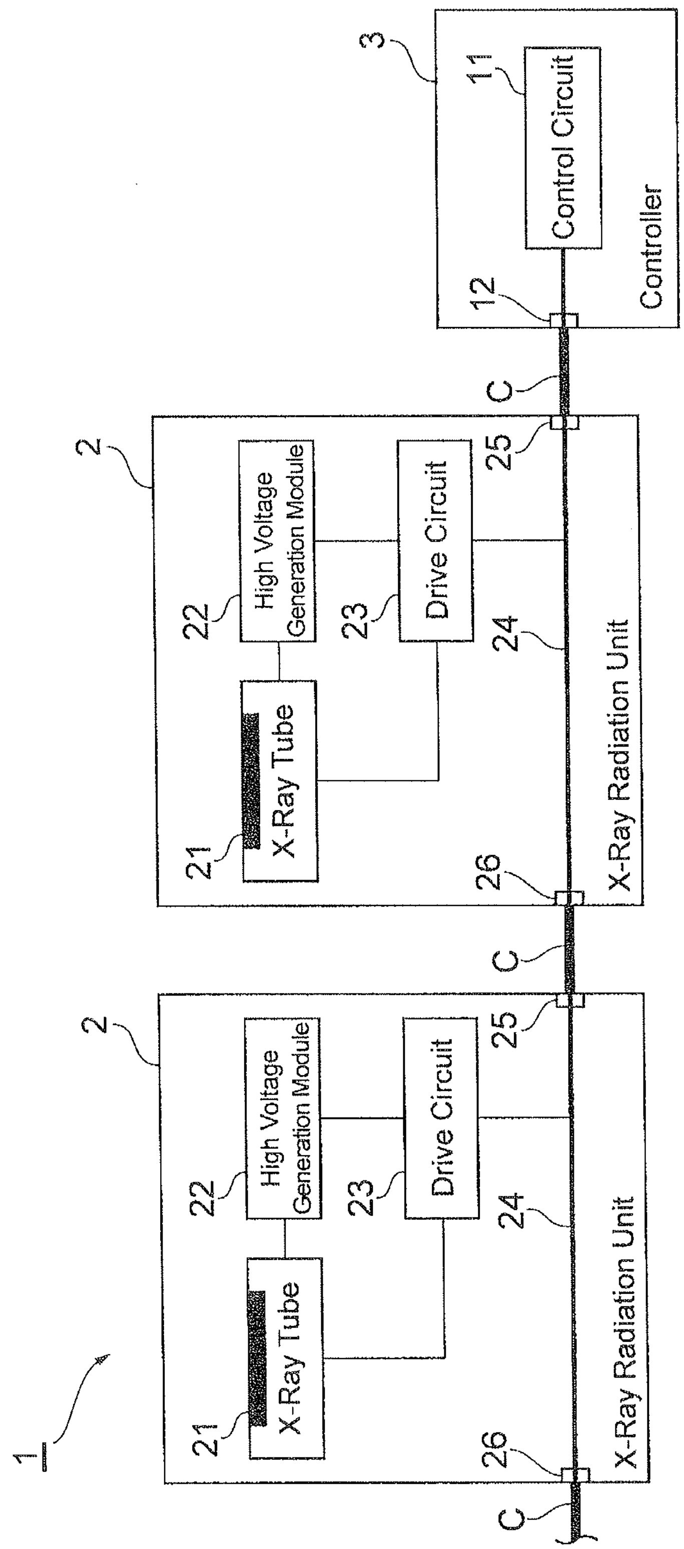


Fig.1

Fig.2



3
11
Control Circuit
12
Controller
C
2
High Voltage Generation Module
22
Drive Circuit
23
25
24
X-Ray Tube
21
X-Ray Radiation Unit
26
C
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22
Drive Circuit
23
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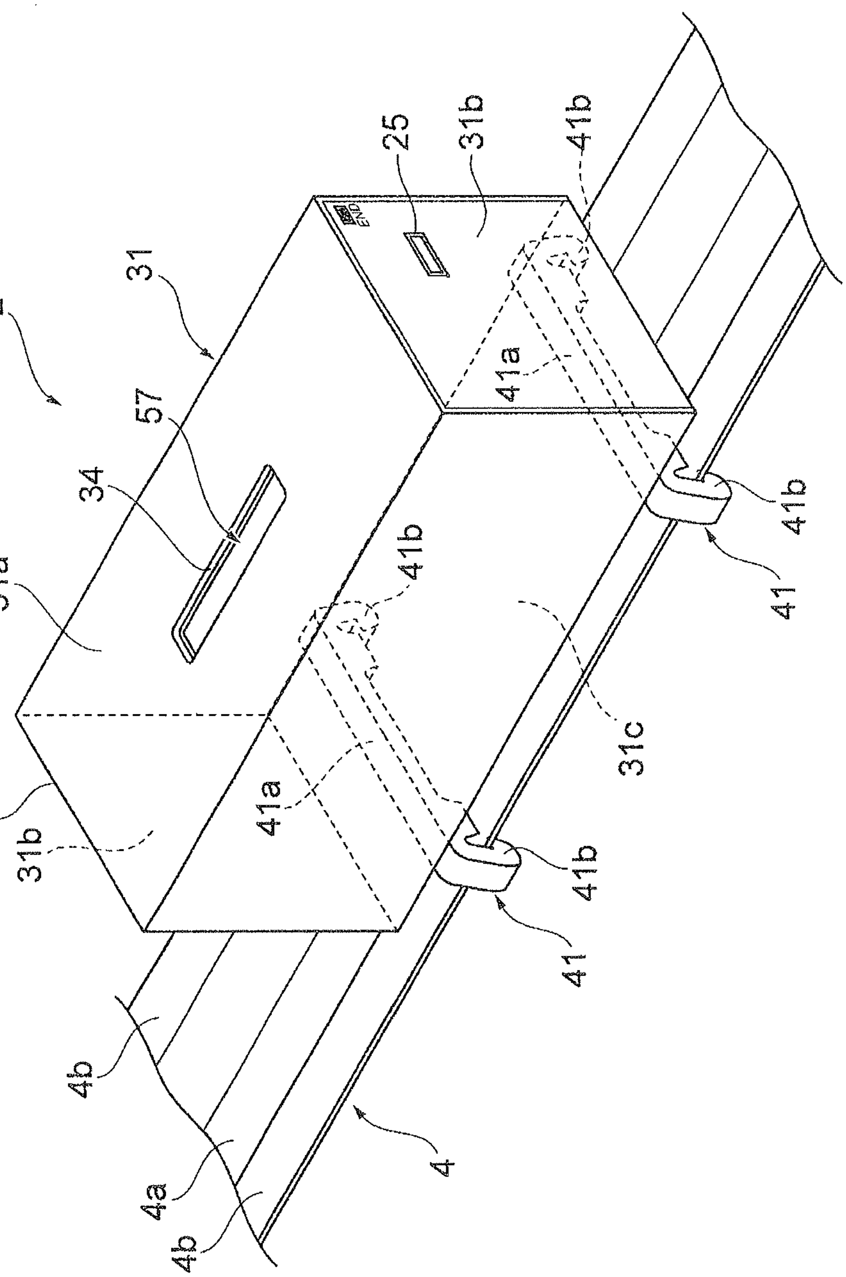
X-Ray Radiation Unit
26
1
C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41
4b
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4b
4
END

Fig.3

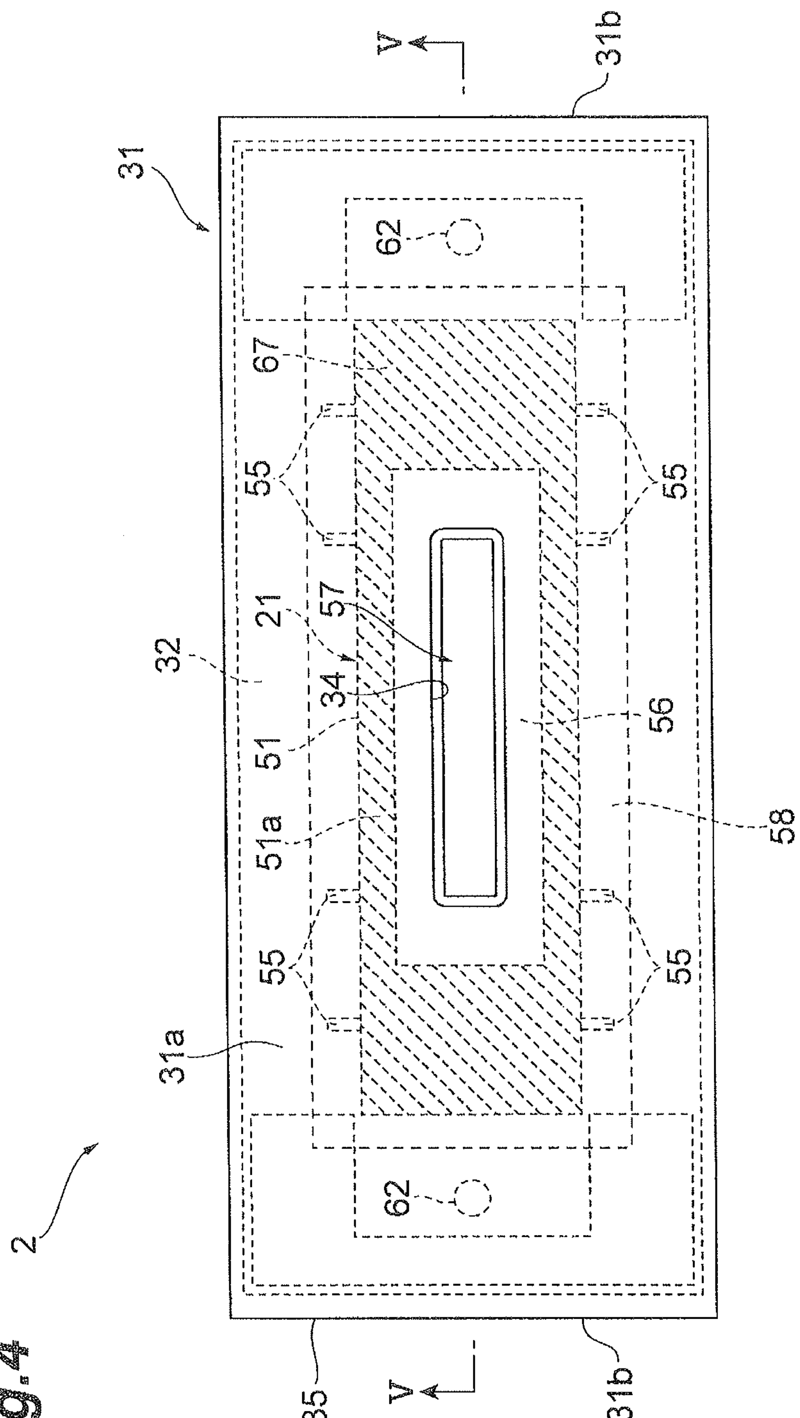

Fig.4

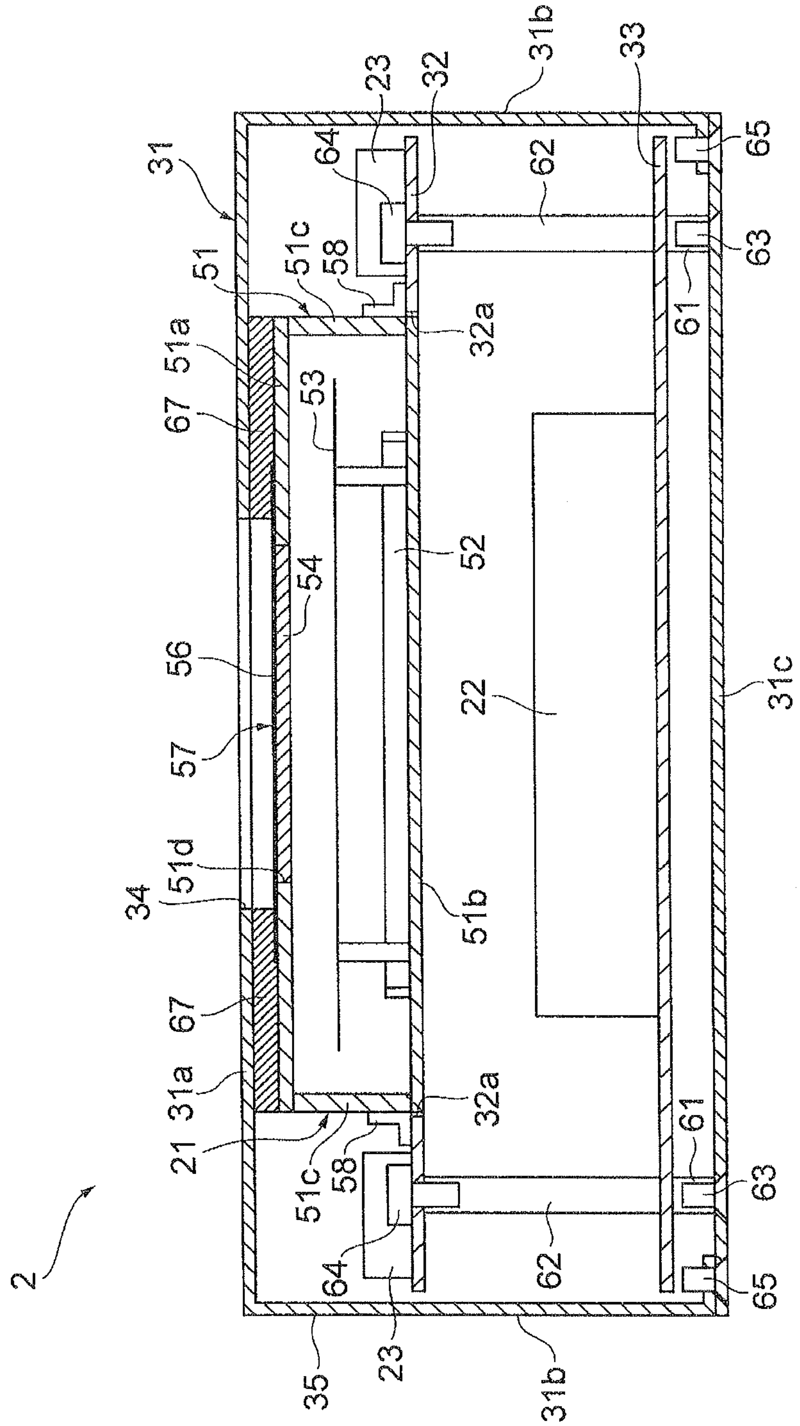

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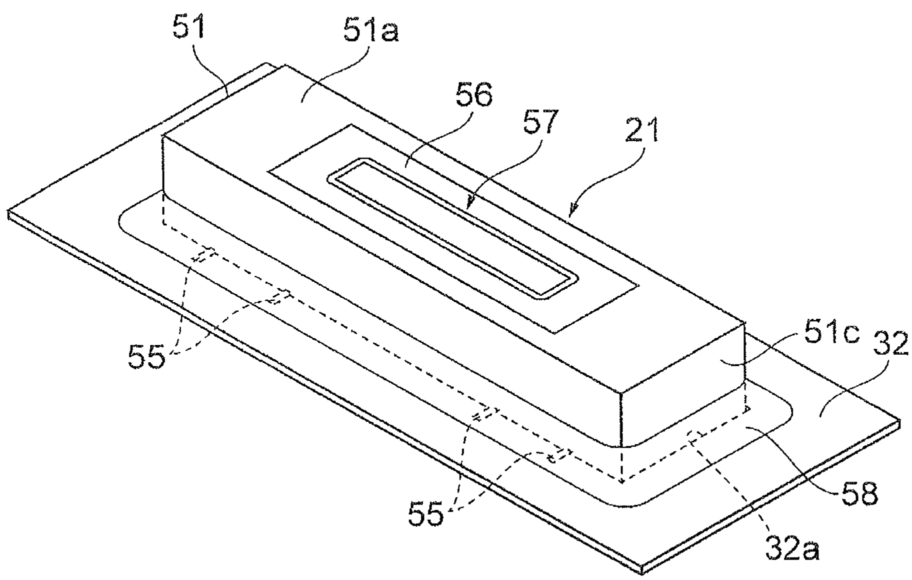
Fig.5

Fig.6

(a)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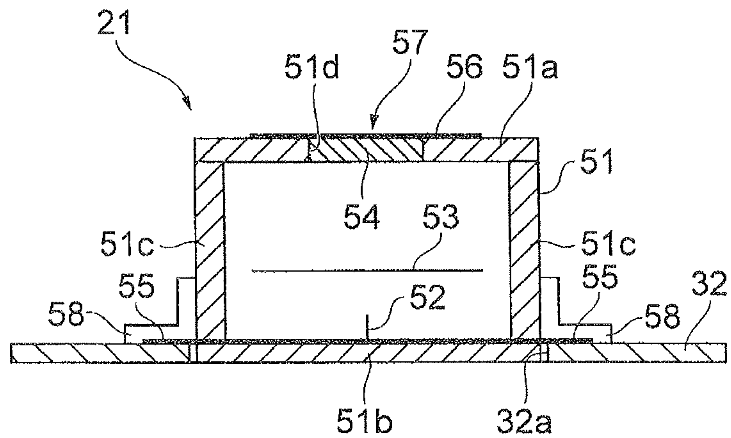
(b)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51b
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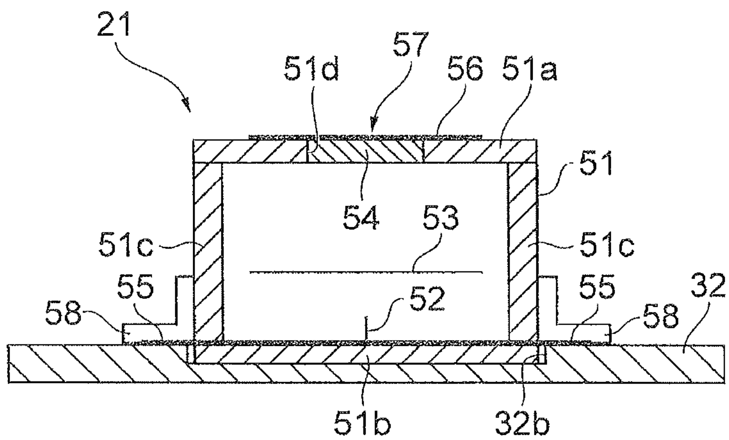
Fig.7

(a)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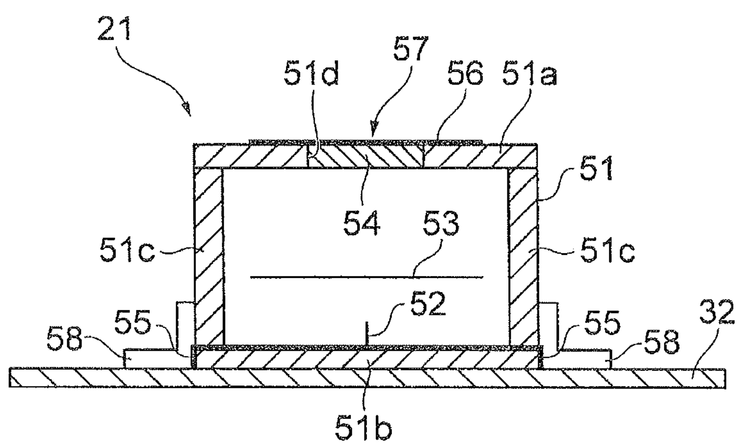
(b)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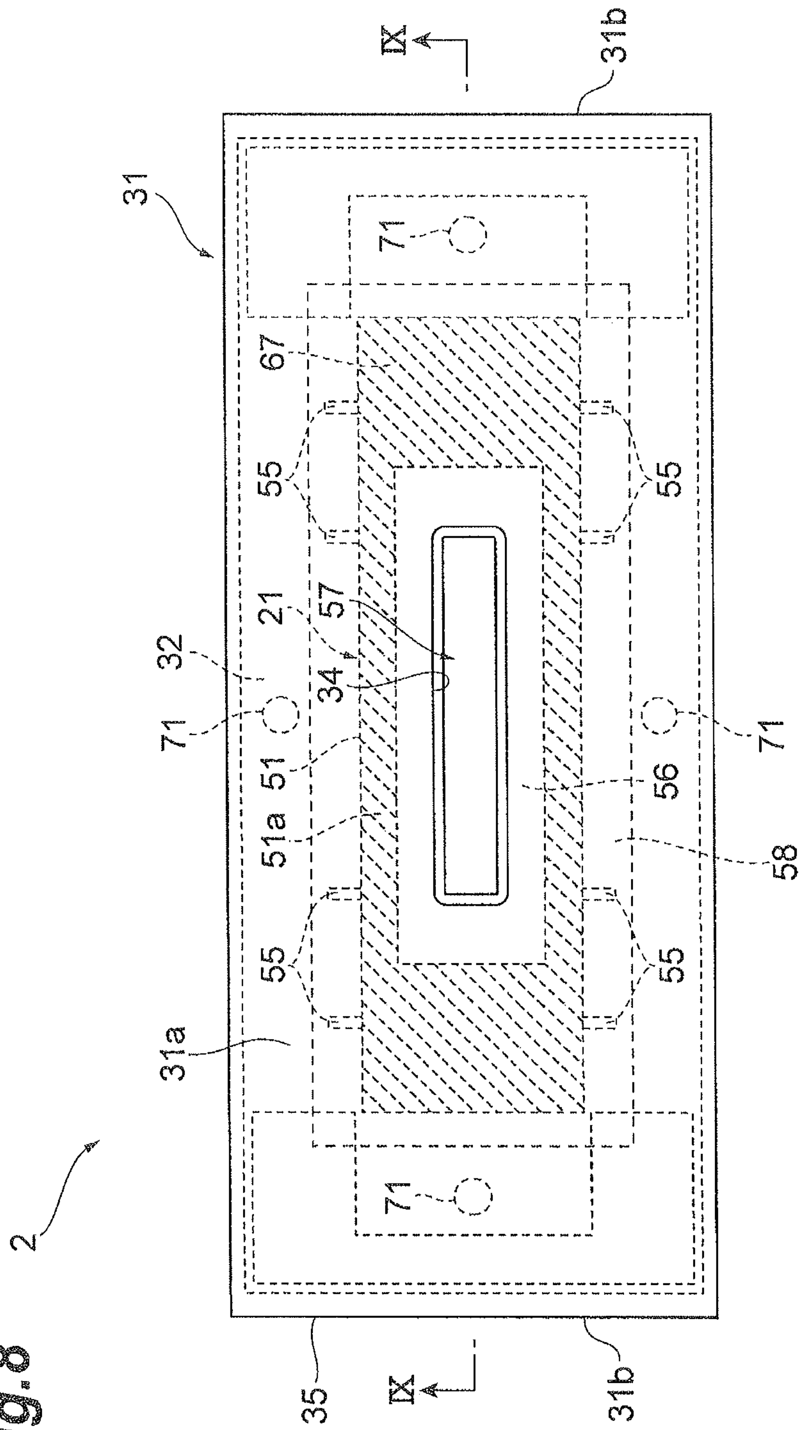
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Fig.8

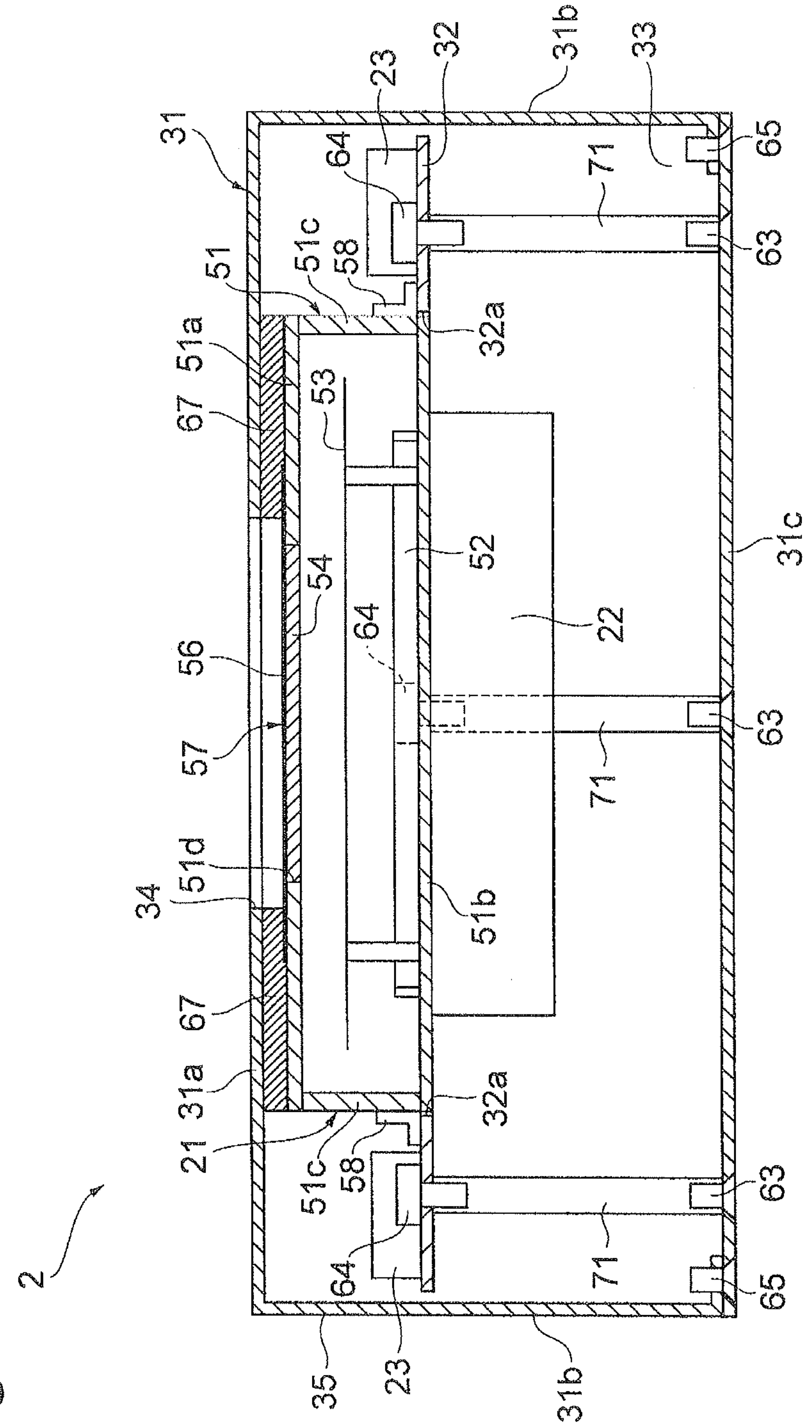
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Fig.9

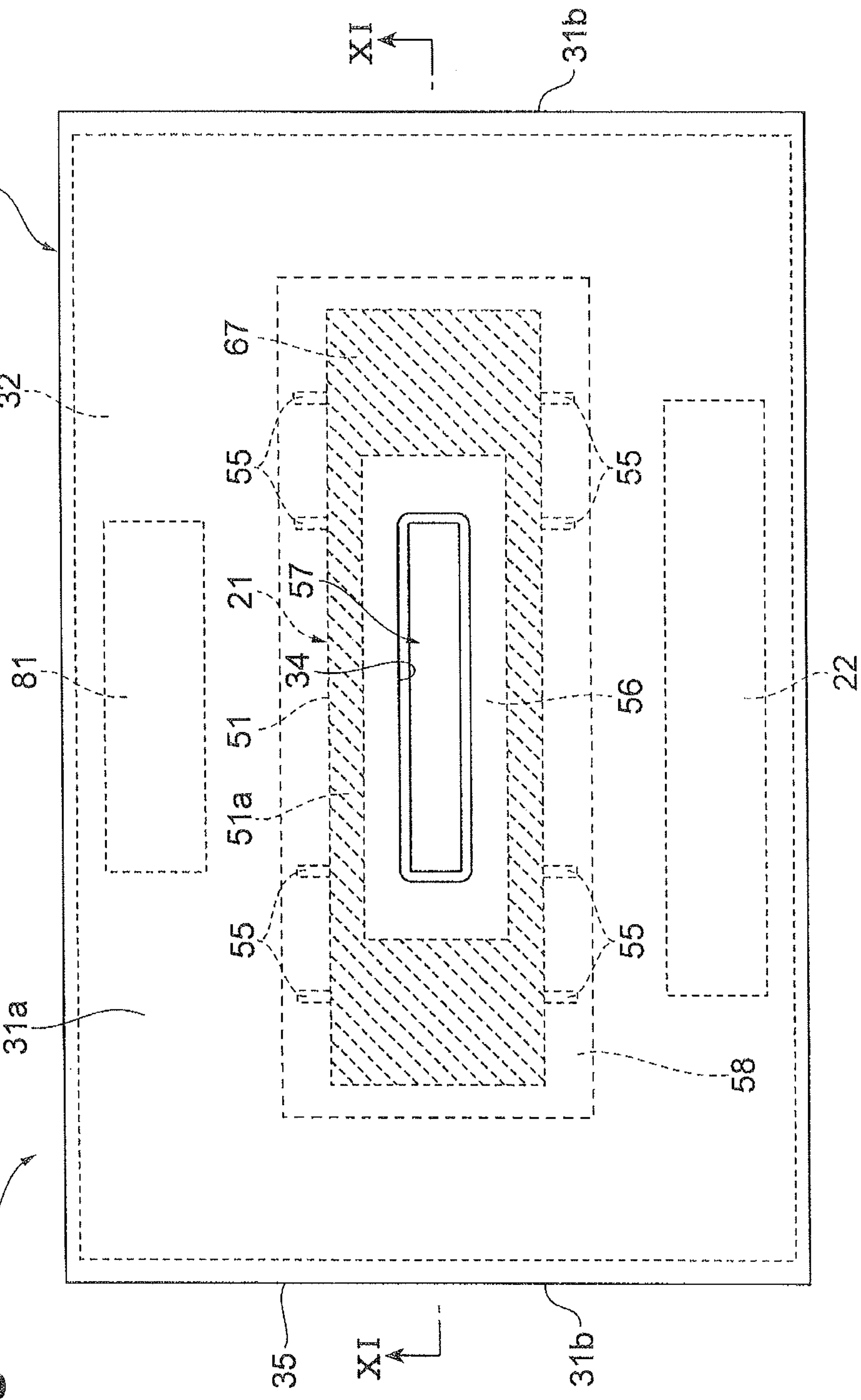

Fig.10

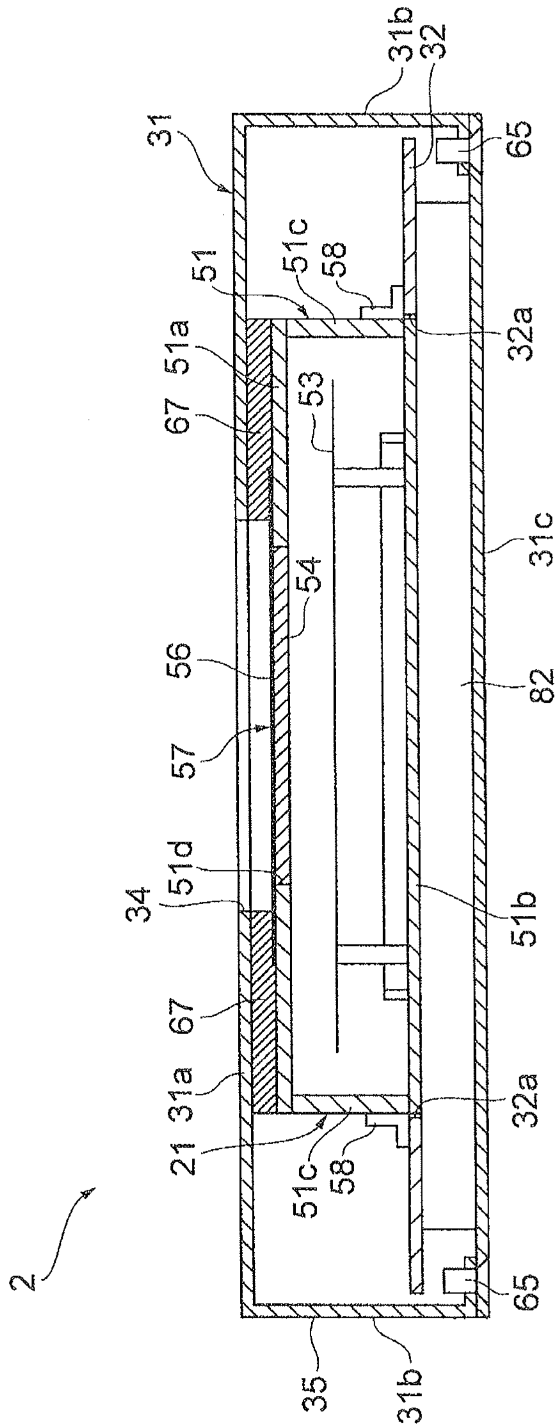
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Fig. 11

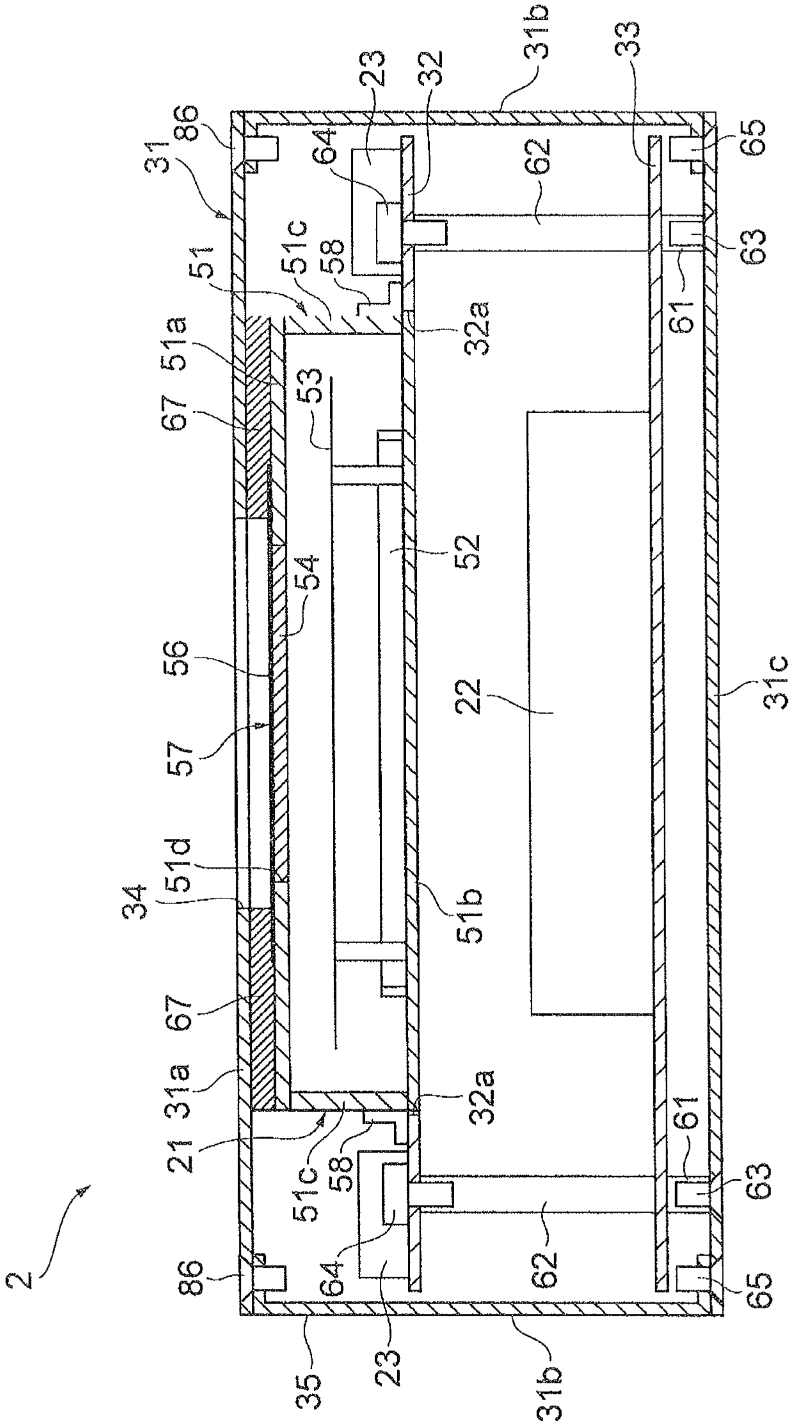

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Fig. 12

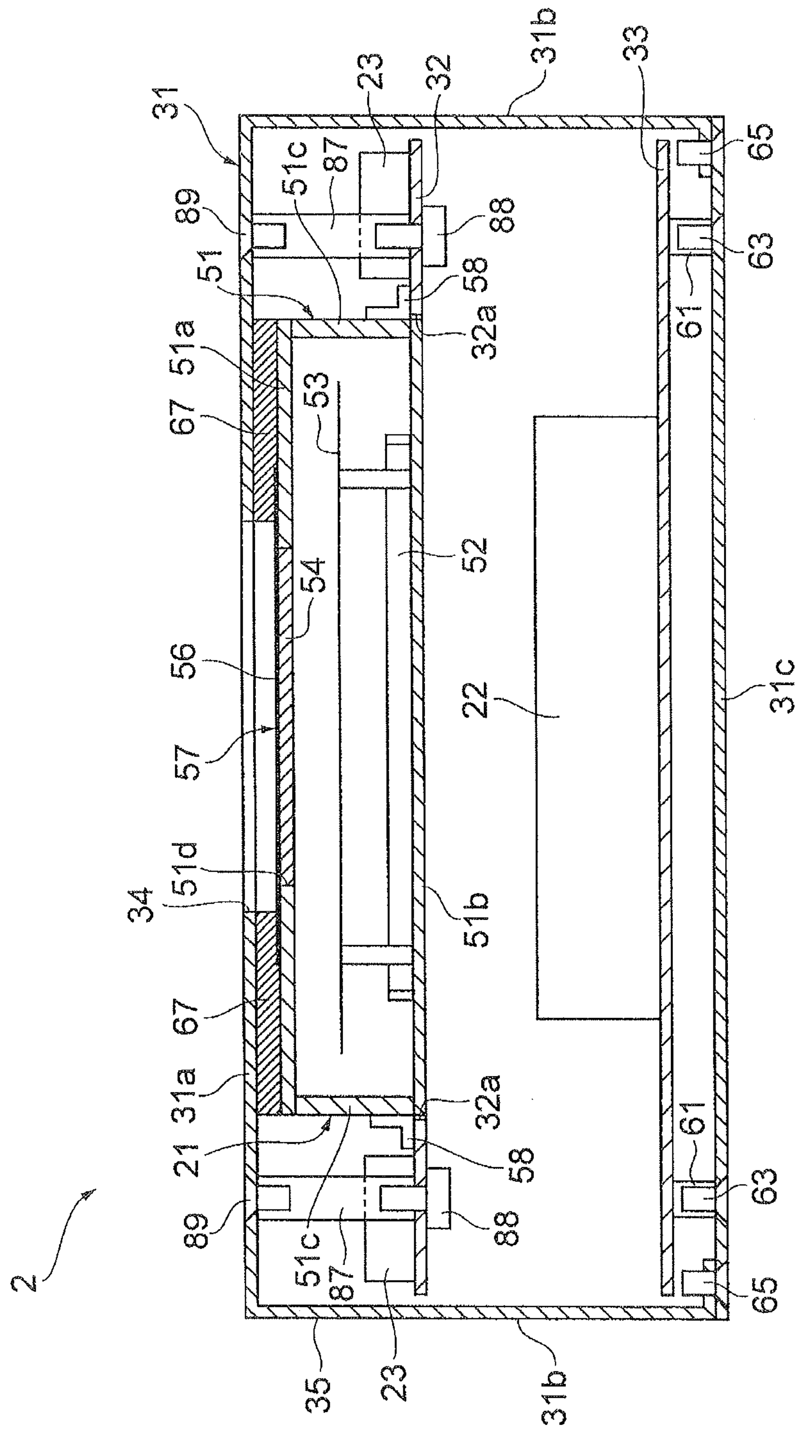

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Fig.13

X-RAY RADIATION SOURCE

TECHNICAL FIELD

The present invention relates to an X-ray radiation source having an X-ray tube within a housing.

BACKGROUND ART

An example of conventional X-ray radiation sources is one disclosed in Patent Literature 1. In this conventional structure, an X-ray tube, a high voltage generation module, and the like are incorporated into a housing having an X-ray emission window, while the X-ray tube is brought into contact with and secured to a mount disposed near the X-ray emission window. In an X-ray generator disclosed in Patent Literature 2, on the other hand, a flange provided about an output window in an X-ray tube is brought into contact with and secured to an inner wall surface of a housing.

CITATION LIST

Patent Literature

Patent Literature 1: U.S. Pat. No. 4,034,251
Patent Literature 2: Japanese Patent Application Laid-Open No. 2000-67790

SUMMARY OF INVENTION

Technical Problem

From the viewpoint of stabilizing outputs of X-rays, it is very important to secure an X-ray tube stably within a housing. However, the X-ray tube is hard to secure stably by substantially fixing only one end side thereof as in Patent Literature 1. On the other hand, fixing at a plurality of locations as in Patent Literature 2 can stabilize the securing, but may complicate the structure due to a plurality of fixing members.

For solving the problem mentioned above, it is an object of the present invention to provide an X-ray radiation source which can stably secure an X-ray tube within a housing without complicating its device structure.

Solution to Problem

For achieving the above-mentioned object, the X-ray radiation source in accordance with the present invention is an X-ray radiation source comprising an X-ray tube for outputting an X-ray from an output window, a first circuit board for mounting the X-ray tube, and a housing containing the X-ray tube and first circuit board and having a wall part formed with an X-ray emission window for emitting to the outside the X-ray outputted from the X-ray tube, the X-ray tube being secured to the housing while being pressed against an inner surface of the wall part by the first circuit board.

In this X-ray radiation source, the X-ray tube is secured to the housing while being pressed against the inner surface of the wall part by the first circuit board. The X-ray tube can be secured stably within the housing by being held between the first circuit board and the wall part. In this X-ray radiation source, the first circuit board incorporated into the housing itself is used for pressing the X-ray tube. This makes it unnecessary to provide a separate member for pressing the X-ray tube and prevents the device structure from becoming complicated.

Preferably, a conductive buffer member is arranged between the X-ray tube and the inner surface of the wall part so as to come into contact with at least a part of the output window. This can stably secure the X-ray tube within the housing while mitigating stresses applied to the X-ray tube by the pressing. Since the buffer member is conductive, the housing and output window can have the same potential, thereby allowing the X-ray tube to operate stably.

Preferably, the housing has a main part having the wall part and a lid part for securing thereto the X-ray tube and first circuit board, the lid part being fastened to the main part by a fastening member so as to press the X-ray tube against the inner surface of the wall part. This can stably secure the X-ray tube in a simple structure.

Preferably, the X-ray tube and first circuit board are supported by a spacer member erected on the lid part. This allows the spacer member to press the X-ray tube securely against the inner surface of the wall part, while securing a fixed accommodation space within the housing, thereby making it possible to improve the degree of freedom in arranging circuit constituent members.

Preferably, the X-ray radiation source further comprises a high voltage generation module for raising a voltage supplied to the first circuit board and a second circuit board for mounting the high voltage generation module, the high voltage generation module and second circuit board being supported at a position closer to the lid part than are the X-ray tube and first circuit board by the spacer erected on the lid part. In this case, not only the X-ray tube, but the high pressure generation module having a relatively large structure is also contained in the accommodation space, whereby the space within the housing can be utilized effectively.

Preferably, the X-ray tube is provided with a laterally-projecting power pin, the first circuit board is provided with a through hole corresponding to a two-dimensional form of the X-ray tube, and the power pin is connected to an edge part about the through hole while a part of the X-ray tube is located within the through hole, so that the X-ray tube is held by the first circuit board. This makes it easy to align the X-ray tube and the first circuit board with each other. Since a part of the X-ray tube is located within the through hole, the housing can be made thinner by the depth of the through hole.

Preferably, the X-ray tube is provided with a laterally-projecting power pin, the first circuit board is provided with a depression corresponding to a two-dimensional form of the X-ray tube, and the power pin is connected to an edge part about the depression while a part of the X-ray tube is located within the depression, so that the X-ray tube is held by the first circuit hoard. This makes it easy to align the X-ray tube and the first circuit board with each other. This also allows the first circuit board to press the X-ray tube firmly. Since a part of the X-ray tube is located within the depression, the housing can be made thinner by the depth of the depression.

Advantageous Effects of Invention

The present invention can stably secure the X-ray tube within the housing without complicating the device structure.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective view illustrating an embodiment of an X-ray radiation device including an X-ray radiation source in accordance with the present invention;

FIG. **2** is a block diagram illustrating functional constituents of the X-ray radiation device depicted in FIG. **1**;

FIG. **3** is a perspective view of the X-ray radiation source illustrated in FIG. **1**;

FIG. **4** is a plan view of FIG. **3**;

FIG. **5** is a sectional view taken along the line V-V of FIG. **4**;

FIG. **6** is a set of diagrams illustrating an example of structures for securing the X-ray tube and the first circuit board to each other;

FIG. **7** is a set of diagrams illustrating other examples of structures for securing the X-ray tube and the first circuit board to each other;

FIG. **8** is a plan view illustrating a modified example of the X-ray radiation source;

FIG. **9** is a sectional view taken along the line IX-IX of FIG. **8**;

FIG. **10** is a plan view illustrating another modified example of the X-ray radiation source;

FIG. **11** is a sectional view taken along the line XI-XI of FIG. **10**;

FIG. **12** is a sectional view illustrating still another modified example of the X-ray radiation source; and

FIG. **13** is a sectional view illustrating yet another modified example of the X-ray radiation source.

DESCRIPTION OF EMBODIMENTS

In the following, preferred embodiments of the X-ray radiation source in accordance with the present invention will be explained in detail with reference to the drawings. FIG. **1** is a perspective view illustrating an embodiment of the X-ray radiation device including an X-ray radiation source in accordance with the present invention. The depicted X-ray radiation device **1** is constructed, for example, as a photoionizer (photoirradiation-type electrostatic remover) which is placed in a clean room or the like in a production line handling a large glass sheet and removes electricity of the large glass sheet by irradiation with X-rays.

The X-ray radiation device **1** comprises a plurality of X-ray radiation sources **2** for emitting X-rays, a controller **3** for controlling the X-ray radiation sources **2**, and a rail member **4** for holding the X-ray radiation sources **2** in a row. The rail member **4** has a channel part **4***a* having a substantially U-shaped cross section formed with a depression directed away from the X-ray radiation sources **2** and flange parts **4***b*, **4***b* projecting laterally from the end portion of the channel part **4***a*. The rail member **4** is formed from a conductive metal such as aluminum, aluminum alloy, iron, or iron alloy, for example, and secures a strength sufficient for holding the plurality of X-ray radiation sources **2**. The rail member **4** is not required to be formed integrally, but may be one detachably connecting separate members which are separated from each other along their longitudinal direction (extending direction). This can yield a holding structure with a desirable form and size according to the size, number, arrangement, and the like of objects to be processed, thereby making it possible to remove electricity by more efficient X-ray radiation.

FIG. **2** is a block diagram illustrating functional constituents of the X-ray radiation device **1**. As illustrated in this diagram, a controller **3** includes a control circuit **11**. The control circuit **11** includes a power circuit for supplying power to X-ray tubes **21** incorporated in the X-ray radiation sources **2**, a control signal transmission circuit for transmitting control signals to the X-ray tubes **21** for driving and stopping them, and a life notification signal receiving circuit for receiving from the X-ray tubes **21** a life notification signal indicating that the X-ray tubes **21** have come to the end of their life, for example. Through an I/O terminal **12**, the control circuit **11** can externally be connected to the X-ray radiation units **2** and the like.

On the other hand, each X-ray radiation source **2** includes the X-ray tube **21** for generating X-rays, a high voltage generation module **22** for raising a voltage supplied from the power circuit, and a drive circuit **23** for driving the X-ray tube **21** and high voltage generation module **22**. A trunk line **24** is connected to the drive circuit **23** and can externally be connected to the other X-ray radiation units **2**, the controller **3**, and the like through input and output terminals **25**, **26** respectively provided at both ends thereof.

In the X-ray radiation device **1**, as illustrated in FIGS. **1** and **2**, the output terminal **26** of one X-ray radiation source **2** is detachably connected to the input terminal **25** of another X-ray radiation source **2** adjacent thereto through a relay cable C. While the X-ray radiation sources **2** are similarly connected to each other up to the X-ray radiation unit **2** at the leading end, the I/O terminal **12** of the controller **3** is detachably connected to the input terminal **25** of the X-ray radiation unit **2** at the base end through the relay cable C. This connects the trunk lines **24** of the X-ray radiation sources **2** in series and the driving circuits **23** of the X-ray radiation sources **2** in parallel to the control circuit **11**.

This structure makes the voltage value inputted from the input terminal **25** equal to the voltage outputted from the output terminal **26** in one X-ray radiation source **2**, and also makes the voltage value outputted from the output terminal **26** of one X-ray radiation unit **2** equal to each of the voltage value inputted from the input terminal **25** and the voltage value outputted from the output terminal **26** in another X-ray radiation unit **2** electrically connected to the former X-ray radiation unit **2**. Therefore, even when a plurality of X-ray radiation source units **2** are connected in series, the same value of voltage can be supplied to all the X-ray radiation source units **2**. Hence, when the X-ray radiation source units **2** are electrically connected to each other, the control circuit **11** of the controller **3** including the power circuit is not required to be connected to the X-ray radiation units **2** individually, whereby the number of X-ray radiation units **2** to be connected can be increased and decreased without complicating their wiring.

The structure of the above-mentioned X-ray radiation source **2** will now be explained in detail.

FIG. **3** is a perspective view of the X-ray radiation source illustrated in FIG. **1**. FIG. **4** is a plan view of FIG. **3**, while FIG. **5** is a sectional view taken along the line V-V of FIG. **4**. As illustrated in FIGS. **3** to **5**, the X-ray radiation source **2** has, within a substantially rectangular parallelepiped housing **31** made of a metal such as stainless steel or aluminum, the above-mentioned X-ray tube **21** and high voltage generation module **22**, a first circuit board **32** mounting at least a part of the X-ray tube **21** and drive circuit **23**, and a second circuit board **33** mounting the high voltage generation module **22**.

As illustrated in FIG. **3**, the housing **31** comprises a rectangular wall part **31** formed with an X-ray emission window **34** for emitting to the outside the X-rays generated from the X-ray tube **21**, a main part **35** having side wall parts **31***b* provided at respective sides of the wall part **31***a* and opening on one surface side, and a lid part **31***c* attached so as to close the opening portion of the main part **35** and is at a ground potential. The X-ray emission window **34** is constructed by an opening which is formed into a rectangle, whose longer sides extend longitudinally of the housing **31**, at a substantially center portion of the wall part **31***a*.

As illustrated in FIG. **3**, a plurality of joint members **41** are used for attaching the housing **31** to the rail member **4**. For example, each joint member **41** is formed from an insulating elastic resin material and comprises a rod-shaped main part **41***a* having a rectangular cross section and a length substantially equal to the width of the rail member **4** (in a direction orthogonal to the extending direction of the rail member **4**) and claws **41***b*, **41***b* respectively formed at both ends of the main part **41***a*. The main part **41***a* is secured to the lid part **31***c* by screwing or the like, and the claws **41***b*, **41***b* are engaged with respective end portions of the flange parts **4***b*, **4***b*, whereby the X-ray radiation source **2** is detachably attached to the rail member **4**. The main part **41***a* may be attached to the lid part **31***c* by not only screwing but also bonding or welding. As illustrated in FIG. **1**, the joint member **41** may additionally be attached between the X-ray radiation sources **2**, **2**, so as to bind a middle part of the relay cable C, which connects the X-ray radiation sources **2**, **2** to each other, to the rail member **4**.

The X-ray tube **21** has, within a vacuum envelope **51** having a substantially rectangular parallelepiped form sufficiently smaller than the housing **31**, a filament **52** for generating an electron beam, a grid **53** for accelerating the electron beam, and a target **54** for generating X-rays in response to the electron beam incident thereon. The vacuum envelope **51** comprises a rectangular wall part **51** made of a conductive material (e.g., a sheet of a metal such as stainless steel) provided with an output window **57** which will be explained later, a wall part **51***b*, made of a rectangular insulating material (e.g., glass), facing the former wall part **51***a*, and a side wall part **51***c*, made of an insulating material (e.g., glass), extending along the outer edges of the wall parts **51***a*, **51***b*. The height of the side wall part **51***c* is smaller than the lateral length of the wall parts **51***a*, **51***b*. That is, the vacuum envelope **51** has a planar, substantially rectangular parallelepiped form whose sides constituting the height are the shortest so that the wall parts **51***a*, **51***b* can be regarded as a flat plane. At a substantially center portion of the wall part **51***a*, an opening **51***d* a bit smaller than the X-ray emission window **34** is formed into a rectangle whose longer sides extend along the longitudinal direction of the vacuum envelope **51** (the longitudinal direction of the wall parts **51***a*, **51***b*). The opening **51***d* constitutes the output window **57** that will be explained later.

The filament **52** is arranged on the wall part **51***b* side, while the grid **53** is placed between the filament **52** and the target **54**. A plurality of power pins **55** (see FIG. **4**) are connected to each of the filament **52** and grid **53**. The power pins **55** pass through the interstice between the side wall part **51***c* and the wall part **51***b* and project respectively to both sides in the width direction of the vacuum envelope **51**. As illustrated in FIG. **5**, a rectangular window material **56** made of a favorably radiolucent, conductive material such as beryllium, silicon, or titanium, for example, is closely secured to the outer surface side of the wall part **51***a* so as to seal the opening **51***d*, thereby constructing the output window **57** through which the X-rays generated at the target **54** is outputted from the X-ray tube **21** to the outside. The target **54**, which is made of tungsten, for example, is formed on the inner surface of the window material **56**.

For securing the X-ray tube **21** and the first circuit board **32** to each other, as illustrated in FIGS. **6**(*a*) and **6**(*b*), a rectangular through hole **32***a* slightly larger than the two-dimensional form constructed by the outermost edges of the wall part **51***b* of the X-ray tube **21** is formed at a substantially center portion of the first circuit board **32**. The depth of the through hole **32***a*, i.e., the thickness of the first circuit board **32**, is substantially the same as the thickness of the wall part **51***b* in the vacuum envelope **51**. Placing the wall part **51***b* within the through hole **32***a* while connecting the power pins **55** to an edge part about the through hole **32***a* on one surface side of the first circuit board **32** with a conductive member such as a brazing material allows the X-ray tube **21** to be held by the first circuit board **32** and electrically connected to the circuits on the first circuit board **32**. Further, a potting part **58** formed from an insulating resin is provided so as to cover junctions between the first circuit board **32** and the individual power pins **55**. The potting part **58** is formed over the whole periphery of the vacuum envelope **51** while bridging the vacuum envelope **51** and the first circuit board **32** and also assists in securing the X-ray tube **21** to the first circuit board **32**. For securing the high voltage generation module **22** and the second circuit board **33** to each other, on the other hand, the second circuit board **33** is not formed with a through hole and the like, whereby the high voltage generation module **22** is secured by bonding and the like to one surface side of the second circuit board **33** facing the first circuit board **32** as illustrated in FIG. **5**.

For securing the X-ray tube **21** and the first circuit board **32** to each other, when the first circuit board **32** has a sufficient thickness, a depression **32***b* slightly larger than the two-dimensional form constructed by the outermost edges of the wall part **51***b* of the X-ray tube **21** may be formed as illustrated in FIG. **7**(*a*) instead of the above-mentioned through hole **32***a*. Preferably, in this case, the X-ray tube **21** is arranged such that the wall part **51***b* is located within the depression **32***b* while the power pins **55** are in contact with the edge part about the depression **32***b* on one surface side of the first circuit board **32**.

It is not always necessary to form the through hole **32***a* or depression **32***b*, and the vacuum envelope **51** of the X-ray tube **21** may be mounted as it is on one surface side of the first circuit board **32** as illustrated in FIG. **7**(*b*). In this case, for example, the power pins **55** may be extended along the side faces of the wall part **51***b*, so as to come into contact with the first circuit board **32**. In any mode, the power pins **55** may be formed not only to project laterally of the vacuum envelope **51**, but also to be routed to the side faces and bottom face of the wall part **51***b* or the outer surface of the side wall part **51***c*, for example, as long as they are electrically and physically in contact with the first circuit board **32**.

As illustrated in FIGS. **4** and **5**, a two-stage structure constructed by spacer members **61**, **62** is employed for securing the X-ray tube **21**, high voltage generation module **22**, first circuit board **32**, and second circuit board **33** within the housing **31**. Each of the spacer members **61**, **62** is formed into a rod from ceramics or various resin materials such as polyimide, nylon, and epoxy, for example, and is not conductive. Two pairs of the spacers **61**, **62** are arranged at respective locations longitudinally holding the vacuum envelope **51** therebetween.

Each of the first-stage spacer members **61** is vertically mounted on the inner surface side of the lid part **31***c* by fastening a screw **63**, and each of the second-stage spacer members **62** is joined to the leading end of the first-stage spacer member **61** while holding and securing the second circuit board **33** mounted with the high voltage generation module **22**. The first circuit board **32** mounted with the X-ray tube **21** is secured substantially in parallel with the second circuit board **33** to the leading end of the second-stage spacer member **62** by fastening a screw **64**.

The lid part **31***c* provided with such a structure is positioned such that the output window **57** of the X-ray tube **21** is exposed through the X-ray emission window **34** of the housing **31**, while being secured to the main part **35** by fastening screws **65**. Fastening the screws **65** causes the first circuit board **32** to press the X-ray tube **21** against the inner surface of the wall part **31***a* in the housing **31**. The length of the second-stage spacer member **62** is on the order of several times that of the first-stage spacer member **61**, so that the first circuit board **32** and the high voltage generation module **22** are separated from each other. The first circuit board **32** and high voltage generation module **22** may be connected to each other with a wire or wirelessly.

As illustrated in FIGS. **4** and **5**, a buffer member **67**, made of steel wool, conductive mat, or conductive rubber, for example, which is conductive and cushionable is arranged between the X-ray tube **21** and the wall part **31***a*. The buffer member **67** comprises an opening part for exposing the output window **57** and a rectangular frame part surrounding the output window **57** so as to come into contact with the peripheral part of the window material **56** and electrically connects the housing **31** and the output window **57** to each other. The X-ray emission window **34** formed in the housing **31** is a bit larger than the output window **57** of the X-ray tube **21**, so as to expose the output window **57** as a whole when seen from above the housing **31** so as to face the wall part **31***a*. This can restrain the edge part of the X-ray emission window **34** from blocking the X-rays emitted with a divergent angle from the output window **57**. All of the materials such as the window material **56**, wall part **51***a*, and buffer member **67** that may be exposed through the X-ray emission window **34** are conductive and electrically connected to the housing **31**.

In the X-ray radiation source **2**, as explained in the foregoing, the lid part **31***c* is fastened to the main part **35** with the screws **65**, whereby the X-ray tube **21** is secured to the housing **31** while being pressed against the inner surface of the wall part **31***a* by the first circuit board **32**. The X-ray tube **21** can be secured stably within the housing **31** by thus being held between the first circuit board **32** and the wall part **31***a*. Since the X-ray tube **21** is secured while, among the surfaces constructing the vacuum envelope **51** of the X-ray tube **21**, the one having a larger area on the wall part **51***a* side formed with the output window **57** is pressed against the inner surface of the wall part **31***a*, this embodiment can secure the X-ray tube **21** more stably, makes it easier for the heat generated at the target **54** to transfer to the housing **31**, and is excellent in heat dissipation efficiency of the X-ray tube **21**. This X-ray radiation source **2** uses the first circuit board **32** incorporated in the housing **31** itself for pressing the X-ray tube **21**. That is, a structure essential for operating the X-ray radiation source **2** also serves as a member for pressing the X-ray tube **21**, which makes it unnecessary to provide a new member for pressing the X-ray tube **21** separately, whereby the device structure can be prevented from becoming complicated.

In the X-ray radiation source **2**, the conductive buffer member **67** is arranged between the X-ray tube **21** and the inner surface of the wall part **31***a* so as to come into contact with the sheet **56** constituting the output window **57**. This enables stronger pressing while mitigating direct stresses applied to the X-ray tube **21** by the pressing, whereby the X-ray tube **21** can be secured more stably within the housing **31**. Since the buffer member **67** is conductive, the housing **31** and the output window **57** can have the same potential, so as to stabilize the potential of the output window **57**, thereby allowing the X-ray tube **21** to operate stably.

In the X-ray radiation source **2**, the spacer members **61**, **62** erected on the lid part **31***c* configure the first circuit board **32** mounted with the X-ray tube **21** and the second circuit board **33** mounted with the high voltage generation module **22** into a two-stage structure, so that the high voltage generation module **22** and second circuit board **33** are supported at a position closer to the lid part **31***c* than are the X-ray tube **21** and first circuit board **32**. Such a structure allows the spacer members **61**, **62** to secure a fixed accommodation space within the housing **31** and divide circuits arranged within the housing **31** into the first and second circuit boards **32**, **33**, whereby the degree of freedom in arranging circuit constituent members can be improved. In particular, the high voltage generation module **22**, which is a relatively large structure on a par with the X-ray tube **21** in the X-ray radiation source **2**, is contained in the accommodation space, whereby the space within the housing **31** can be utilized effectively.

In the X-ray radiation source **2**, the power pins **55** laterally project from the vacuum envelope **51** of the X-ray tube **21**, the first circuit board **32** is provided with the through hole **32***a* corresponding to the two-dimensional form of the X-ray tube **21**, and the power pins **55** are connected to the edge part about the through hole **32***a* while the wall part **51***b* of the X-ray tube **21** is located within the through hole **32***a*, so that the first circuit board **32** holds the X-ray tube **21**. This makes it easier to align the X-ray tube **21** and the first circuit board **32** with each other. Since the wall part **51***b* of the X-ray tube **21** is located within the through hole **32***a*, the thickness of the housing **31** can be reduced by the depth of the through hole **32***a*, whereby the device can be made smaller.

Forming the depression **32***b* instead of the through hole **32***a* as illustrated in FIG. **7**(*a*) can also make it easier to align the X-ray tube **21** and the first circuit board **32** with each other by the depression **32***b* and bring the first circuit board **32** and the X-ray tube **21** directly into surface contact with each other, thereby firmly pressing the X-ray tube **21**. Locating the wall part **51***b* of the X-ray tube **21** within the depression **32***b* can also reduce the thickness of the housing **31** by the depth of the depression **32***b*.

Mounting the vacuum envelope **51** of the X-ray tube **21** as it is on one surface side of the first circuit board **32** as illustrated in FIG. **7**(*b*) can also bring the first circuit board **32** and the X-ray tube **21** directly into surface contact with each other, thereby firmly pressing the X-ray tube **21**. Firmly pressing the X-ray tube **21** against the wall part **31***a* can improve the efficiency of heat transfer from the X-ray tube **21** to the housing **31**, i.e., the heat dissipation efficiency of the X-ray tube **21**.

The present invention is not limited to the above-mentioned embodiment. For example, while the above-mentioned embodiment uses the rod-shaped spacer members **61**, **62**, spacer members may have various forms such as pillars, plates, and frames. The number of spacer members and locations where they are arranged may also be designed as appropriate.

The structure for assembling the X-ray tube **21** and the like within the housing **31** may also be modified accordingly. For example, in an example illustrated in FIGS. **8** and **9**, the first circuit board **32** is provided with a function of the second circuit board **33**, so as to reduce the number of substrates, while spacer members **71** arranged at four locations on both sides in the longitudinal and lateral directions of the X-ray tube **21** support the first circuit board **32**. Each spacer member **71** has a length substantially equal to the total length of the couple of spacer members **61**, **62** illustrated in FIG. **5**, thereby securing a space between the first circuit board **32** and the lid part **31***c*. The high voltage generation module **22** is secured to a surface of the first circuit board **32** on the side opposite from the X-ray tube **21**.

Such a structure can make the housing **31** thinner by reducing the number of circuit boards. Supporting the first circuit board **32** with the spacer members **71** at four locations allows the first circuit board **32** to press the X-ray tube **21** uniformly, whereby the X-ray tube **21** can be secured more stably within the housing **31**. The length of the spacer members **71** may be shorter than the total length of a pair of spacer members **61**, **62** as long as a space necessary for arranging the high voltage generation module **22** can be formed thereby.

In an example illustrated in FIGS. **10** and **11**, for instance, a housing **31** having an area larger than the first circuit board **32** illustrated in FIGS. **4** and **5** and the first circuit board **32** are used, an arrangement region **81** for the drive circuit **23** for driving the X-ray tube **21** is provided on one side in the width direction of the X-ray tube **21** on one surface side of the first circuit board **32**, and the high voltage generation module **22** is mounted on the other side. A frame-shaped spacer member **82** is secured to the lid part **31***c*, while the first circuit board **32** is fixed to the leading end of the spacer member **82**. Such a structure can make the housing **31** thinner by reducing the number of circuit boards. Supporting the first circuit board **32** with the frame-shaped spacer member **82** allows the first circuit board **32** to press the X-ray tube **21** uniformly, whereby the X-ray tube **21** can be secured more stably within the housing **31**.

In an example illustrated in FIG. **12**, for instance, an extension is provided along the inner surface of the wall part **31***a* in the side wall part **31***b* of the housing **31**, and the extension and end portions of the wall part **31***a* are fastened with screws **86**. As a consequence, the X-ray tube **21** is pressed not only against the inner surface of the wall part **31***a* by the first circuit board **32**, but also against the first circuit board **32** by the inner surface of the wall part **31***a*. Therefore, the X-ray tube **21** is further firmly held between the first circuit board **32** and the inner surface of the wall part **31***a* and thus can be secured more stably within the housing **31**.

In an example illustrated in FIG. **13**, for instance, spacer members **87** are provided between the first circuit board **32** and the wall part **31***a* in place of the spacer members **62** arranged between the first and second circuit boards **32**, **33**. A screw **88** is fastened to one end part of each spacer member **87** through the first circuit board **32**, while a screw **89** is fastened to the other end part of the spacer member **87** through the wall part **31***a*. In such a structure, the X-ray tube **21** is pressed not only against the inner surface of the wall part **31***a* by the first circuit board **32**, but also against the first circuit board **32** by the inner surface of the wall part **31***a*. Therefore, the X-ray tube **21** is further firmly held between the first circuit board **32** and the inner surface of the wall part **31***a* and thus can be secured more stably within the housing **31**.

It is not always necessary to use spacer members within the housing. In this case, for example, the lid part **31***c* itself may be provided with a projection projecting into the housing **31**, so as to press the first circuit board **32**. The side wall part **31***b* may also be provided with a projection adapted to act similarly.

REFERENCE SIGNS LIST

1: X-ray radiation device; **2**: X-ray radiation source; **21**: X-ray tube; **22**: high voltage generation module; **31**: housing; **31***a*: wall part; **31***c*: lid part; **32**: first circuit board; **32***a*: through hole; **32***b*: depression; **33**: second circuit board; **34**: X-ray emission window; **35**: main part; **55**: power pin; **57**: output window; **61**, **62**, **71**, **82**, **87**: spacer member; **65**, **86**, **88**, **89**: screw (fastening member); **67**: buffer member

The invention claimed is:

1. An X-ray radiation source comprising:

an X-ray tube for outputting an X-ray from an output window;

a first circuit board for mounting the X-ray tube; and

a housing containing the X-ray tube and first circuit board and having a wall part formed with an X-ray emission window for emitting to the outside the X-ray outputted from the X-ray tube;

wherein the X-ray tube is secured to the housing while being pressed against an inner surface of the wall part by the first circuit board.

2. An X-ray radiation source according to claim **1**, wherein a conductive buffer member is arranged between the X-ray tube and the inner surface of the wall part so as to come into contact with at least a part of the output window.

3. An X-ray radiation source according to claim **1**, wherein the housing has a main part having the wall part and a lid part for securing thereto the X-ray tube and first circuit board;

wherein the lid part is fastened to the main part by a fastening member so as to press the X-ray tube against the inner surface of the wall part.

4. An X-ray radiation source according to claim **3**, wherein the X-ray tube and first circuit board are supported by a spacer member erected on the lid part.

5. An X-ray radiation source according to claim **4**, further comprising a high voltage generation module for raising a voltage supplied to the first circuit board and a second circuit board for mounting the high voltage generation module;

wherein the high voltage generation module and second circuit board are supported at a position closer to the lid part than are the X-ray tube and first circuit board by the spacer erected on the lid part.

6. An X-ray radiation source according to claim **1**, wherein the X-ray tube is provided with a laterally-projecting power pin;

wherein the first circuit board is provided with a through hole corresponding to a two-dimensional form of the X-ray tube; and

wherein the power pin is connected to an edge part about the through hole while a part of the X-ray tube is located within the through hole, so that the X-ray tube is held by the first circuit board.

7. An X-ray radiation source according to claim **1**, wherein the X-ray tube is provided with a laterally-projecting power pin;

wherein the first circuit board is provided with a depression corresponding to a two-dimensional form of the X-ray tube; and

wherein the power pin is connected to an edge part about the depression while a part of the X-ray tube is located within the depression, so that the X-ray tube is held by the first circuit board.

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